AN

INAUGURAL DISSERTATION
ON THE
PRODUCTION OF ANIMAL HEAT:

READ AND DEFENDED AT A

PUBLIC EXAMINATION,

HELD BY THE MEDICAL PROFESSORS, BEFORE THE

REV. JOSEPH WILLARD, *S.T.D. L.L.D.* PRESIDENT,

AND THE

GOVERNORS OF HARVARD COLLEGE,

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TO

NATHAN SMITH, M. B.

THIS

DISSERTATION

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AN

INAUGURAL DISSERTATION.

THE heat of the human body, in health, is generally about ninety ſix degrees of Farenheit's thermometer. Yet ſo admirably is the economy of man adapted to the variations of heat, as not to be materially affected by it, excepting in its extremes.

MAN can dwell in all climates, free of danger, from the intenſe cold of Siberia and Spitbergen, where mercury congeals ſpontaneouſly in the thermometer, to the perpendicular rays of Amazonia. Nay more, Doctor Fordyce has by experiment proved, that man can exiſt in a room, walled with bricks and gradually heated to the degree of boiling water, *i. e.* two hundred and twelve degrees;

degrees ; and all theſe variations of place and temperature ; a difference of three hundred and thirty two degrees, or more, without deſtroying life, producing diſeaſe, or altering the temperature of the common maſs of fluids, but a few degrees, from the ſtandard ninety ſix.

It is ſurpriſing wherein conſiſts the cauſe of this equilibrium of animal heat, whether the ſubject be expoſed to the freezing blaſts of the pole or ſcorching beams of the equinoctial ſun.

Animals therefore have a power of generating heat, when placed under the poles ; and a ſtill more ſurpriſing power of reſiſting the introduction of heat or generating cold, when in a heated room.

In the firſt inſtance the fluids are guarded from congelation, and in the ſecond prevented from paſſing into elaſtic gaſes ; both of which principles are wanting in the vegetable kingdom.

WHAT havoc heat and froſt make in the huſbandman's plantations! where a few hours midday ſun or midnight froſt, lays waſte many months of labour; mars the beauty of the fields, and diſappoints the expecting huſbandman.

OF all the phenomena of the animal economy, none is more ſtriking, none more worthy the attention of philoſophers, than thoſe, which accompany the function of reſpiration. Little as we are acquainted with the object of this ſingular operation, we are ſatisfied that it is eſſential to life, and that it cannot be ſuſpended for any length of time, without expoſing the animal to immediate death or imminent danger. It is univerſally known that air is the agent or rather the ſubject of reſpiration. But at the ſame time there are ſome kinds of air, which will not ſupport life, in the higher order of animals.

THERE have been almoſt as many theories, as writers, on animal heat. It is perhaps need-leſs and unſeaſonable for me to enter into an inveſtigation of them. Some have ſuppoſed it to be generated by the tendency of the fluids and ſolids to putrefaction; others attributed it to the attrition of the blood in circulation.

We will obſerve the different proceſſes, by which heat is known to be generated. Theſe may be confined to two; which are, firſt, Combination and Decompoſition; ſecond, Friction.

We will take a curſory view of theſe, and ſee which beſt agrees with the phenomena of animal heat.

First, of

COMBINATION AND DECOMPOSITION.

THE theory of combuſtion is now explained on the abſorption of the vital principle from the air; and ſetting at liberty the azotic and carbonic principles, which ariſe in ſmoke.

THAT the air is decompoſed and robbed of ſome of its conſtituent parts, which it poſſeſſed previous to its expoſure to the burning body, and is combined with ſome other matter, which did not before appear in it, is evident from comparing atmoſpheric air, previous to combuſtion, with the ſame afterwards; the *former*, of its common purity, M. d' Lavoiſier found, by experiments, to conſiſt of ,27 of oxygen, ,73 of azote, and ,01 of carbonic acid;* the *latter* conſiſts of little or no oxygen at all, a ſmall ſhare of azote, but perhaps one half is carbonic acid.

THE union of concentrated acids with water, quick lime, pure alkalis, or metals, is productive of a ſtrong heat; but the combination of the nitric acid with certain oily ſubſtances is ſo powerful this way as to cauſe inflammation.

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* Theſe names were firſt introduced by the French, in their new Nomenclature, inſtead of the old terms, vital, impure, and fixed air.

Let us compare theſe phenomena with thoſe of animal heat, and notice the agreement between them. It will be firſt aſked *where are*, and *of what* conſiſt, the combination and decompoſition? Will it be thought ſufficient if I ſay, in the lungs, during reſpiration, a part of the air is combined with the blood, and *that* in its turn ſends off carbone* with the air expired.

This proceſs appears ſimilar to combuſtion, the ſmoke of which is exactly ſimilar to our breath expired; the preſence of oxygen is neceſſary to the ſupport of the one as well as the other, during both of which the caloric† of the oxygen is ſeparated from the air; their reſidues are totally unfit to ſupport reſpiration or combuſtion, until they are again oxygenated. This, not being thoroughly underſtood, has been treated as *hypothetical.*‡

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* This is the coaly principle, the baſe of carbonic acid.

† Matter of heat.

‡ Cullen's Phyſiology.

Therefore, having found it impoſſible to account for it on theſe principles, reſort was had to

FRICTION,

WHICH we find was the favourite theory of moſt of the antients, as it has been that of the moderns. This theory was powerfully ſupported by the celebrated Cullen, who ſaith that the cauſe of animal heat is "the motion of the blood."

Since friction has been generally attributed as the *generating cauſe* of animal heat, we need not be ſurpriſed at the many hypotheſes advanced reſpecting the manner *in which*, and the parts *on which*, it operated to produce it.

I am diſpoſed to favour and ſupport a theory, which attributes the production of animal heat to the combination and decompoſition of air and blood, in their paſſage through the lungs, during the act of reſpiration; by which the caloric in the air is diſengaged from its conſtituents, and appears combined with the blood; which may be deduced from this: the expired air having loſt its caloric, which it poſſeſſed before inſpiration; and the blood having acquired an additional quantity of it, to what it had previous to its entering the lungs.

In ſupport of this, I ſhall firſt notice ſome general facts reſpecting the air's containing caloric. Then, that this caloric is diſengaged from the air in its paſſage through the lungs. Thirdly, that a decompoſition of the blood takes place at the ſame time. Fourthly, that there is a combination of ſome ſubſtance with the air expired. And, laſtly, that a certain matter is combined with the arterial blood in the lungs.

Those truely ingenious philoſophers, Doctors Black and Crawford, have proved, by a number of nice experiments, (which it would be difficult to give a juſt idea of without engravings) that the caloric is contained in the oxygen; and that *expired* air contains only one third part of the heat, which was contained in it previous to inſpiration; it follows that the former muſt neceſſarily have given off its exceſs of abſolute heat in the lungs.

The comparative heat of florid arterial blood is, to that of venous, as eleven and an half to ten; the heat of that blood, which is returned from the lungs, is greater than it was previous to its entering them, from which it muſt have received its ſupply.

We may conclude from hence, that, in the lungs,during the proceſs of reſpiration, a quantity of abſolute heat is ſeparated from the air, and combined with the blood.

Dr. Crawford has inferred, from experiments, that, in the converſion of arterial blood into venous in the capillaries, the heat is diſengaged from the arterial blood, and combines with the ſurrounding ſubſtances. So that venous blood muſt have, by far, leſs ſpecific heat, than what appeared juſt before in the arterial; and, if that, on its arrival in the lungs, ſhould be converted into arterial blood, without receiving any ſupply of abſolute heat from the air, its ſenſible heat would be ſo diminiſhed, as to fall from ninety ſix degrees, to below the freezing point.

In a warm medium, the ſame animal decompoſes leſs air, in a given time, than in a cold one, alſo leſs heat is diſengaged, the difference of colour in the arterial and venous blood is leſs; and theſe in proportion to the temperature of the circumambient air. A cubic inch of air, of the temperature of two hundred and twelve degrees, contains, by far, leſs oxygen, than when of a temperature one hundred and twenty degrees below 0; and in the docompoſition of equal quantities of air, of ſo different temperatures, an amazing exceſs of heat will be in favour of the cold air. Hence inflammatory diſeaſes are moſt prevalent in the cold ſeaſons; it is this, which, in animals, wards off the deſtructive effects of cold in the polar regions.

On the other hand, the quantity of caloric being very trifling, that is diſengaged from the warm air, inſtead of increaſing the heat of the arterial blood, it does not equal the cold produced by the converſion of venous into arterial blood; and, inſtead of increaſing the heat, it generates cold. On this, and evaporation, it is that man is capable of enduring an atmoſphere heated two hundred and twelve degrees, without ſuſpending the functions of life.

The air is decompoſed in its paſſage through the lungs, and the caloric diſengaged from it.

Atmospheric air, or that which we reſpire, is a heterogeneous fluid, compoſed of oxygen, azote, and carbonic acid. The former maintains life by reſpiration, and fire by combuſtion; both the latter are totally unfit for either of thoſe purpoſes.

Oxygen is alſo a compound, conſiſting of a principle of ſolidity and caloric, fire, or the matter of heat. Caloric is moſt abundant in oxygen; other airs, ſuch as air expired, ſmoke,

&c. contain but little if any at all; in any air that is nearly proportional to ~~this~~ its power of ſupporting life.

An animal, placed in a veſſel containing air, as ſoon as it is nearly all changed by reſpiration, ſickens, is convulſed, and dies, if not removed. This happens inſtantaneouſly in carbonic acid, almoſt as ſoon in azote, later in atmoſpheric air, and lateſt in oxygen, which ſupports life about four times as long as atmoſpheric air, and is perhaps the much celebrated PABULUM VITÆ of the antients.

In the third place, we have to ſhow that there is a decompoſition of the blood, in the lungs, during reſpiration.

The venous blood, when brought to the lungs, is of a dark modena red, which is produced by the preſence of a large quantity of hydrogene or azote, and abſence of oxygen. To prove this the following experiments were inſtituted, two ligatures were made on the jugular vein of a living cat, one half of the blood contained between the ligatures was drawn off, the vein filled with hydrogene; an hour after the blood, being drawn from the vein, was fluid, but had acquired a colour almoſt as dark as ink. At, and for, the ſame time, an equal quantity of blood was intercepted between two ligatures, on the crural vein of the ſame animal. This blood, being drawn from the vein, was found in ſome meaſure coagulated, but miſcible with water; communicating, by far, leſs colour to it than the former. Hence it may be inferred; that, when hydrogene or azote are in contact with the blood, they increaſe its colour and diminiſh its tendency to coagulation.

We will ſhortly ſtate how hydrogene and azote may be introduced into the circulating maſs.

Blood attracts hydrogene and azote, which are ſeparated from animal ſubſtances, by heat and a tendency to putrefaction.

The colour of the arterial blood is a light ſcarlet; it undergoes the ſame change in completing a circulation, as by expoſure to hydrogene or azote. Therefore, we may conclude, that it is united with theſe, in ſome part of its routine, and perhaps in the capillaries, where they are ſeparated by heat and the putrefactive proceſs. Theſe, united with the blood, account for the dark grumous colour of it in the vena portarum, where it has abſorbed an unuſual quantity from the ſemiputreſcent contents of the alimentary canal. The air, contained in the large inteſtines, is moſtly hydrogene.

The greater the heat of the animal, and tendency to putrefaction, the more *impure air* will be diſengaged, and the venous blood darkened proportionally.

We have now to conſider the combination of ſome ſubſtances with the air expired, which did not appear in it, when inſpired; theſe are fixed air and carbone.

An expiration conſiſts of fixed air, hydrogene, + azote. ~~and carbone.~~

The preſence of fixed air is proved by its precipitating lime water, when agitated with it.

The quantity of carbonic acid is greatly increaſed by reſpiration (where the oxygen combining with the carbone, in the proportion of ſeventy two to twenty eight, forms pure carbonic acid) inſtead of being one part in an hundred, as in atmoſpheric air, makes, perhaps, one tenth of the whole expiration.

Fourcroy obſerves, that carbonic acid is produced by reſpiration, combuſtion of coals, and is exhaled from plants in the ſhade; is inſtantaneouſly fatal to animals, and extinguiſhes flaming tapers.

Azote ariſes moſtly from putrefying animal matters; is very noxious to animals and flames.

The preſence of theſe two gaſes is the cauſe of the great fatality obſervable in tight bed chambers, where a pan of coals has been added to ward off the cold, during a winter's night; in priſon and cartel ſhips, hoſpitals, jails, &c. where numbers are crowded together, without proper ventilation.

This is evident, from the ſymptoms of thoſe, who languiſh, being the ſame as are obſervable, when introduced into carbonic acid, or azote, as mentioned above, they firſt appear ſtupified, ſoon agitated; reſpiration becomes laborious and hurried; from this, the ſymptoms of diſtreſs faſt increaſe, till ſubſultus tendinum and convulſions cloſe the ſcene with death.

The ſame cauſe we give for the production of endemic diſeaſes in compact towns, during the hot ſeaſons of the year, when the putrefactive proceſs ſeizes all inanimate animal ſubſtances and many vegetables, diſengaging therefrom the noxious azote, which remains ſtagnant for want of a current of air to diſperſe it.

LASTLY,

We have to ſpeak of caloric, which is combined with the arterial blood in the lungs.

THIS is ſeparated from the air in reſpiration, and changes the colour of the *venous*, to a light ſcarlet, and greatly increaſes the abſolute heat of the *arterial* blood.

To prove this, the experiment above related may be introduced, with this difference; introduce oxygen into the vein in lieu of hydrogene. The blood when drawn will be of a moſt beautiful ſcarlet. Alſo, expoſe a glaſs of venous blood to the action of oxygen, the ſame effect will be produced; or ſprinkle it with a neutral ſalt, as muriate of ſoda, nitrate of potaſh, &c. which, on decompoſition, are known to ſend forth a large portion of oxygen, and we ſhall ſee the ſurface changing rapidly to a light ſcarlet.

WHEN two or more bodies are united by the attraction of compoſition or glandular attraction, their temperature ſuffers a change. The oxygen is combined with the blood in the lungs by this attraction of compoſition, and there eliminates a part of its heat; but when it arrives at the capillaries, which are actually glands, a new attraction of compoſition, with a glandular attraction, eliminate the remainder, which was the greateſt part of the caloric.

The heat of the arterial blood is, to the venous, as eleven and an half to ten ; this is ſufficiently eſtabliſhed by direct experiments.

From the preceding obſervations, may be drawn the following inferences : animal heat, and heat ſent forth by combuſtion, depend on the ſame cauſe. Animals, who reſpire little or no air, are always cold ; ſuch are fiſhes, toads, lizards, inſects, ſerpents, &c. whoſe arterial blood is deſtitute of that florid redneſs.

RESPIRATION,

THEREFORE, appears to be but combuſtion in a leſs degree, in which atmoſpheric air is decompoſed in its paſſage through the lungs, is robbed of its vital principle, caloric of the oxygen, which is combined with the blood, and with it diffuſed through every and the minuteſt part of the ſyſtem, ſpreading its genial warmth and animating every fibre ; till, in the capillary veſſels, it is exchanged for hydrogene and azote, where the blood parts with its ſcarlet hue for a dark modena red ; ſurcharged with theſe new properties, it returns to the lungs, where they are diſpoſed of and a new routine commences.

In this manner then, is animal heat generated ; and all parts of the body receive conſtant ſupplies from this great fountain of heat, the lungs.*

Man does not receive his natural warmth from the temperature of the ſurrounding atmoſphere.

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* The author, ſince reading his Diſſertation, has found ſome obſervations in Dr. Darwin's Zoonomia, which correſpond ſo nearly with his own opinion and obſervations, that he was almoſt perſuaded to introduce them to elucidate this work ; but to abridge is a *delicate taſk*. However, he hopes thoſe, who are not fully perſuaded of the truth of this theory, will conſult that juſtly celebrated work ; particularly Section XXIII. 4. Section XXXVIII. and Claſs II. 1. 1. 2.

moſphere. Why ſhould we expect his body to be of the temperature of Spitbergen or Amazonia, as he may chance to inhabit one or the other place ? We find the principles of animal heat innate with him, and never diminiſhing nor increaſing beyond bounds ; although the ſurrounding atmoſphere ſhould vary three hundred and thirty two degrees, or more. Such is the wonderful economy of nature.

It may be aſked, if combuſtion and reſpiration be ſimilar proceſſes, why does not light and flame appear from the one as well as the other ? The anſwer is plain, the proceſs of RESPIRATION is like combuſtion, but accompliſhed in a *much more gradual manner* ; the rapidity of the former ill ſuits the ſlow progreſs of the latter. However, the phenomena of the two bear the ſame affinity to each other, as the phenomena of the *ſudden* and *general*, the *moderate* and *partial* combination of nitric acid with oil. The former burſts into flame, ſhewing light, heat and all the phenomena of combuſtion ; but the latter is more moderate, like reſpiration, not being accompanied with any ſigns of light or flame, but all the other phenomena of the former, as heat, &c. Nevertheleſs the two proceſſes are identically the ſame, only differing in degree.

Perhaps theſe obſervations have been couched in too chemical terms, to be ſtrictly adapted to the animal economy, which is not to be compared to a chemiſt's laboratory; but the proceſs is ſo ſimilar to a chemical DOUBLE ELECTIVE ATTRACTION, that, without this order, the definition could not have been perfect.

The fœtus, egg, and ſeed, receive their vivifying heat from the parent animal or earth; but as ſoon as the animal is uſhered into perfect exiſtence, we find it capable of generating this principle, independent of its parent, but the vegetable, ever ſo perfectly formed, is dependent on its parent earth for exiſtence.

HERACLITUS maintained that FIRE was the vivifying principle of all bodies, both animal and vegetable. The ingenious Dr. Brown has added that their exiſtence, growth and maturation depend on ſomething, which acts from without, and this a "ſtimulus."

LIVING animals and vegetables have, beſides the common properties of matter, a peculiar ſomething, which diſtinguiſhes them from dead ones ; in theſe we ſee all the ſolids and fluids too : what then is lacking ? A gentle oſcillation, or motion of the fluids, a circumgiration of the liquors, which is produced and continued through life by a certain ſomething, abſorbed from the air.

OUR ingenious profeſſor, in a "Diſcourſe on the Principles of Vitality," obſerves, "it is a portion of that ſubtle electric fluid, which fills the immenſe ſpace of the whole univerſe, pervades all bodies, and actuates every particle of matter. By it the phenomena of magnetiſm, fire, and light are produced ; and on it the various and aſtoniſhing phenomena of VEGETATION and ANIMATION depend."

THE arterial blood, having received the caloric, from the lungs, is directly diſtributed to every part of the body, and in every part is changed into venous blood, in the operation of which, it diſengages the matter of heat, and abſorbs a proportional quantity of hydrogene and azote, which are plentifully ſupplied from fermenting and putrefying matters ; the greater the quantity of hydrogene and azote, yielded in any one place, the greater will be the quantity of heat exchanged for it in that place : inſtance fermentation in the ſtomach, called heart burn, what an increaſe of *heat* in that region.

ALSO,

PUTRID FEVERS,

IN which, to the accelerated velocity of the blood add, that the ſolids and fluids are tending to putrefaction ; hence an unuſual quantity of hydrogene and azote will be yielded, and an unuſual quantity of heat will be exchanged for them at the converſion of arterial into venous blood. To theſe cauſes it is probably owing that the heat of the human body is greateſt in theſe fevers.

LOCAL inflammation is accompanied with redneſs, tumour, and unuſual heat, with increaſed circulation, and at length with a ſtagnation of ſerous fluid, which is effuſed into the adjoining cellular ſubſtance, the putrefactive proceſs, commencing, the heat in the part is then greateſt.

IN the ſtate of health, the motion of the blood through the different parts of the ſyſtem, and the hydrogene and azote with which the blood is ſupplied in theſe parts, is adjuſted ſo exactly to each other that the exchange is equal through every part of the ſyſtem.

BUT if by any exceſs the balance be deſtroyed, as by increaſed circulation, or by a tendency to putrefaction, it is evident that a greater quantity of heat will be extricated in that part, in a given time; this heat will ſtimulate the veſſels into more frequent and forcible contractions, by which the velocity of the blood, and conſequent extrication of heat will be ſtill farther increaſed. On this principle we may probably account for the partial heats, which are produced by topical inflammations, and thoſe, which ariſe in hectic and nervous complaints. So the fire increaſes in that place where the air is gently agitated by the bellows.

Dr. Crawford obſerves that the doctrine which reſults from his experiments on animal heat, will probably lead to an explanation of the uſes of the ſpleen and lymphatic glands.

May not the ſpleen, ſays he, be intended partly to apply a proper degree of heat to the left ſide of the ſtomach, and partly to ſupply the liver with azotic blood? As a quantity of fire is extricated, during the converſion of arterial into venous blood, in the capillaries, if blood, which is changed in the ſpleen, had paſſed to the liver, as arterial blood, and had been changed into venous in that organ, it ſeems evident there would have been a redundancy of heat in the right hypochondriac region, and a deficiency of it in the left.

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